In conclusion, it appears to me that the close relationship of the metals aluminium, gallium, indium, iron, and chromium, makes it probable that molecules of both formulæ M_2R_6 and MR_3 may be capable of existence in the case of all these metals, even though the conditions necessary for the stability of the higher molecules have not yet been attained for indium and chromium chlorides. That the conditions have been attained in the case of the chlorides of aluminium, gallium, and iron, appears to me to admit of no doubt. SYDNEY YOUNG.

University College, Bristol, March 23.

Luminous Night-Clouds.

IN accordance with my anticipations (see *Astr. Nachr.*, 2885), luminous night-clouds have now been seen at the southern point of South America. Herr Stubenrauch, meteorological observer at Punta-Arenas, writes to me that he twice saw the phenomenon in December 1888. According to the same observer, it was noticed several years ago by a naval officer in the Beagle Channel, rather to the south of Punta-Arenas. The description given by Herr Stubenrauch leaves no room for doubt that the phenomenon is identical with that observed in Europe.

Sternwarte, Berlin, March 28. O. JESSE.

Zodiacal Light Observations.

COULD any of your readers furnish me with a list of observations of zodiacal light, or refer me to any record where such a list can be found? I applied to the Meteorological Office some years ago, and found that no such list was to be obtained. All I require is the precise time of the display, the place of observation, and any other mathematical observations concerning the angle of inclination, &c., which may be relied on.

W. DONISTHORPE.

32 Pembridge Villas, W., March 30.

Vapour, or Meteoritic Particle.

ABOUT 6.30 p.m. on Friday last, while out in the country, I observed a large meteor falling slowly and almost vertically in the north-north-east. After it had disappeared, half-way between the zenith and the horizon, I noticed, in the strong twilight, a faint phosphorescent trail, which did not disappear, but changed to a straw-colour, like a streak of vapour illuminated by the setting sun. Gradually the shaft expanded in the centre and contracted at the ends, until it assumed the shape of a balloon. Continuing to change, it flattened out horizontally like a football, and apparently about half the size; and it looked a little brighter as it became more condensed. This process occupied quite half an hour, and the object remained like a nebulous patch lit up by the sun's rays, until that orb was well below the horizon, finally disappearing about 7.15 p.m. That part of the sky was perfectly clear—there were no clouds except the usual dense bank on the horizon. F. B.

Rugby, March 27.

The Satellite of Procyon.

WITH reference to Mr. Barr's letter on p. 510, I would mention that Mr. Burnham has lately observed Procyon with the 36-inch refractor at the Lick Observatory, and finds no trace of any close companion with powers up to 3300. H. SADLER.

March 29.

RECENT RESEARCHES ON THE RARE EARTHS AS INTERPRETED BY THE SPECTROSCOPE.[1]

IF I name the spectroscope as the most important scientific invention of the latter half of this century, I shall not fear to be accused of exaggeration. Photography has rendered vast services in recording astronomical and biological phenomena, and it even supplies us with indirect means of studying ray vibrations to which the human retina does not respond. The electro-acoustic devices of Edison and his co-workers permit almost magical communication between human beings. Ruhmkorff's coil and the Geissler tube have rendered notable service in physical investigations; and the electric lamp promises to aid in exploring the internal parts of living animals as well as in studying the organic forms of the deep sea. But in the spectroscope we possess a power that enables us to peer into the very heart of Nature. In the extent of its grasp and the varied character of its applicability it surpasses the telescope, and at least rivals the microscope. It enables the astronomer to defy immeasurable distance, and to study the physical condition and the chemical composition of the sun and the stars as if they were within touch, and even to ascertain the direction of their movements.

Without attempting to discuss the import of the results thus gained—which would lead us too far—I may point out that they overthrow a dogma concerning the classification of the sciences. It has been said that the simpler and more general sciences lend both doctrines and methods to the more complex and less general sciences, and that the latter give nothing in return. But we now see chemistry endowing astronomy with an original and fruitful method of research.

Turning to the very opposite extremity of the scientific hierarchy, we find that to the biologist the spectroscope is of value in studying the relations of animal and vegetable fluids, and even of certain tissues. But this wonderful instrument is clearly destined to play its chief part in what is called terrestrial chemistry—the field where it has won the most signal triumphs.

It must be remarked, despite this vast range of applicability—a range sweeping through the whole universe and embracing all the four elements of antiquity—and despite the astonishing results already achieved and the prospect of greater revelations to come, that the spectroscope is still inadequately appreciated by professed men of science, and in consequence is to a great extent ignored by the "educated and intelligent public." In urging its more thorough recognition, I do not advocate the formation of Spectroscopic Societies for the fragmentary study of everything that can be observed with a spectroscope. But I recommend researching chemists to appeal to this instrument wherever requisite and possible.

An elaborate spectroscopic study of the basic constituents of rare minerals from different localities would be of great value, and I would suggest that on all possible occasions meteorites should be submitted to careful spectroscopic analysis.

I do not propose to discuss all the splendid achievements of the spectroscope in chemistry; nor its applications in ordinary analysis, qualitative and quantitative; nor the conduct of technical operations, such as the Bessemer process. I confine myself to the light thrown by the spectroscope upon the nature and the relations of our *elements*, real or supposed.

Though systematically employed by few experimentalists, the spectroscope has already led to the discovery of several hitherto unknown elements. In the early days of spectrum analysis, attention was mainly concentrated on the flame spectra: that is, the bodies in question were vaporized and rendered luminous by the action of a flame, such as that of the Bunsen burner or of the oxyhydrogen jet. This procedure in the hands of Bunsen and Kirchhoff gave us cæsium and rubidium; afterwards, in my own hands, thallium; and in those of Reich and Richter, indium.

Then followed the production and examination of spark spectra. The spark produced by means of the induction coil, especially when its energy is reinforced by the intercalation of a Leyden jar, volatilizes and renders luminous minute portions of matter, solid, liquid, or gaseous, which may then be examined by the spectroscope. In this manner gallium was discovered, in 1875, by Lecoq de Boisbaudran. In consequence of the sharpness and the well-marked character of these spark spectra, they are relied on by chemists as certain proof of the identity of any two elements which yield identical spectra.

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[1] Abstract of Address delivered on Thursday, March 28, at the annual general meeting of the Chemical Society, by the President, Mr. W. Crookes, F.R.S.

Next was introduced the systematic study of the absorption spectra seen when a beam of light is passed through certain transparent solids or through solutions of various substances. One of the earliest observers in this branch of spectroscopy was Dr. Gladstone, who, in 1858, read before this Society a paper on the absorption of light by various metallic salts, and gave the first description of the absorption spectrum of didymium. This branch of spectroscopy has proved not less fruitful in the recognition of new metallic elements.

In the investigation of the rare earths my principal object has been to separate the true from the undemonstrated and spurious, verifying the true, rejecting the spurious, and reducing as far as possible the number of the doubtful. In the following table I have given a list of the so-called "rare elements," with which for the last seven or eight years I have been specially occupied.

TABLE.

	Atomic Weight of Metal and Formula of Oxide.	Gives Spectrum by	Component Meta-Elements according to	
			Crookes (1886).	Nilson and Krüss (1887).
Didymium	Neodymium—140·3, Nd_2O_3 Praseodymium—143·6, Pr_2O_3 Unnamed.	Absorption.	Dα λ = 475	Diα Diβ Diγ Diδ Diε Diη Diθ Diι Diχ
Decipium				
Samarium	150·12, Sm_2O_3.	Absorption and Phosphorescence.	Sδ Gε Gγ Gθ	Smα Smβ
Lanthanum	138, La_2O_3.	Phosphorescence.		
Erbium	166, Er_2O_3.	Absorption and Phosphorescence.	λ 550 λ 493	Erα Erβ
Philippium	45—48, PpO.	Phosphorescence.		
Holmium		Absorption.		Xα Xβ Xγ Xδ
Thulium	170·7, Tm_2O_3.	Absorption.		Tmα Tmβ
Dysprosium		Absorption.	λ 457 (1888)—448	Xζ Xε Xη
Yttrium	88·9, Yt_2O_3.	Phosphorescence.	Gα Gβ Gδ Gζ Gη	Zα Tb Yt — Lecoq de Boisbaudran.
Terbium	124·7, Tb_2O_3.			
Gadolinium (Yα)		Phosphorescence.	Gβ Gζ	
Ytterbium	173·01, Yb_2O_3.	Phosphorescence.		
Scandium	44·03, Sc_2O_3.			

Column 1 gives the names by which they are commonly known. Column 2 gives their atomic weights, &c. Column 3 shows in what manner they come under the domain of spectroscopy; and columns 4 and 5 notify the components or meta-elements into which some of these bodies have been decomposed in 1886 by myself, and in 1887 by Krüss and Nilson. In the first column I have exercised a judicial leniency in retaining candidates, for the sake possibly of old associations, when strict justice would have disestablished them. Thus, it may be doubted whether decipium, philippium, or gadolinium should have been retained. But since doubts have been cast on the integrity of nearly all the occupants of this column, the line should not be drawn too strictly.

At first spectroscopic examination was applied directly to substances, natural or artificial, which had not undergone any special preparation. The idea next occurred of attempting to split up substances supposed to be simple into heterogeneous constituents before appealing to the spectroscope. The refined chemical processes used for this operation may be summarized under the name of fractionation, whether they be fractional precipitations, crystallizations, or decompositions. The essential principles of this process were so fully discussed on the last occasion when I had the honour of addressing you that I need not further allude to them.

THE DIDYMIUM GROUP.

A combination of such delicate and prolonged chemical processes with spectroscopic examination applied to bodies showing absorption spectra soon led to important discoveries. When in that year the didymium from samarskite was examined by M. Delafontaine (*Comptes rendus*, vol. lxxxvii. p. 632; *Chemical News*, vol. xxxviii. p. 223), he found it to differ somewhat from ordinary didymium as extracted from cerite and gadolinite, and by a series of chemical fractionations he succeeded in separating from it an earth which he called decipium, giving at least three absorption bands, one having a wave-length of 416 ($1/\lambda^2$ 578); another narrower and stronger, at wave-length 478 ($1/\lambda^2$ 438), and a very faint "minimum of transmission" near the limit of the blue and green. Nine months later, M. Lecoq de Boisbaudran (*Comptes rendus*, vol. lxxxix. p. 212; *Chemical News*, vol. xl. p. 99) announced the discovery of samarium as a constituent of the didymium from samarskite.

Still didymium was not reduced to its ultimate simplicity. In 1885, Dr. Auer von Welsbach (*Monatsh. Chem.*, vi. 477), by fractionally crystallizing the mixed nitrates of ammonium, didymium, and lanthanum, showed it was thus possible to cleave didymium in a certain direction and separate it into two other bodies, one giving green salts and the other pink salts. Each of these has a characteristic absorption spectrum, the sum of the two sets of bands approximating to the old didymium spectrum. These bodies the discoverer has named respectively praseodymium and neodymium. The neodymium spectrum, according to Dr. Auer, consists of the whole of the bands in the red, with part of the large one in the yellow; it then misses all the green and blue, and takes in the second line in the violet. The spectrum of praseodymium takes the other part of the yellow band and all the green and blue, except the second blue, which belongs to neodymium. Subtracting these two spectra from the old didymium spectrum, there are still two bands left at λ 462 and 475 ($1/\lambda^2$ 465 and 443). Assuming that the argument from absorption spectra is a legitimate one—and all recent research tends to show that if not quite trustworthy it is at all events a weighty one—the inference I draw from these results is that the old didymium still contains a third body distinct from neo- and praseo-dymium, to which one or both of these extra bands is due.

I must venture to lay especial emphasis on the words *in a certain direction*. Didymium in my own laboratory has undergone other cleavages, and I have not yet decided whether we shall have to recognize further decompositions of neodymium and praseodymium, or whether the original didymium is capable of being resolved differently according to the manner in which it is treated. Keeping the band in the orange always of the same strength, in many of the fractions of didymium from different sources the other bands of neo- and praseodymium are seen to vary from very strong almost to obliteration (*Chemical News*, vol. liv. p. 27). In this way I have worked on the spectra of didymium from allanite, cerite, euxenite, fluocerite, gadolinite, hielmite, samarskite, yttrotitanite, &c., and the further I carry the examination the more the conclusion is forced upon me that didymium must not be regarded as compounded of two elements only, but rather as an aggregation of many closely allied bodies. Later researches of Messrs. Krüss and Nilson have led them to the same conclusion.

By examining the absorption spectra of solutions of rare earths obtained from widely different sources, MM. Krüss and Nilson (*Berichte der deutsch. chem. Gesellschaft*, vol. xx. Part 12, p. 2134; and *Chem. News*, vol. lvi. pp. 74, 85, 135, 145, 154, 165, 172) came to the conclusion that the elements giving absorption spectra, and known as didymium, samarium, holmium, thulium, erbium, and dysprosium, were not homogeneous, but that each one contained almost as many separate components as it produced bands of absorption.

They have discovered that in didymium obtained from some minerals one of the fainter lines of the normal didymium spectrum is strong, while others usually stronger are almost or quite absent; results to which I shall presently refer will show that this cannot be explained by dilution or concentration. In this way, by examining a great number of minerals, they found anomalies occurred in the case of almost each of the old didymium lines, and therefore decided, as above mentioned, that it is a compound body, capable of resolution into at least nine separate components.

Identical arguments are brought forward to prove that each of the other so-called elements, samarium, erbium, holmium, thulium, dysprosium, &c., are compounds of many closely allied bodies.

Messrs. Krüss and Nilson, I believe, are pushing their investigation with the object of isolating the separate components of these different earths. They, however, question the possibility of resolving the erbia and didymia earths into their several ultimate constituents by a fractionated decomposition of the nitrates. In fact, they assert that by means of the methods of separation at present known it would be almost impossible to completely isolate any single constituent of the mixed earths. They therefore propose, as I had previously done,[1] a method by which we may certainly arrive nearer to the mark and dispense with much tedious fractionation. If we examine the minerals which contain these rare earths, we find they occur in very different states of mixture or combination. Sometimes many of the constituents which we wish to separate are conjointly present, and sometimes but few. The desired differentiation, in fact, has already been commenced by Nature. Krüss and Nilson, therefore, whichever ingredient they wish to separate, propose to operate upon a mineral which contains that ingredient as far as possible in a state of isolation. In other words, they will take advantage of the work that Nature has already begun, and endeavour by refined chemical means to put the last finishing touches to her work. Thus they will be able to work with smaller quantities of primary material,—no small consideration in the case of some minerals,—and to obtain results in a shorter time. How widely the composition of one and the same mineral, as judged by our searching physical tests, may vary, will be seen from the following instances. Fergusonite from Arendal shows six of the bands of holmium, fergusonite from Ytterby four, and that from Hitterö only three. Moreover, the ingredient provisionally called X*a* is to be found in the fergusonite from Ytterby, but not in that of Arendal and Hitterö.

The foundation for thus firmly declaring what I had previously ventured to infer, is the striking differences in the spectra given by several specimens of one earth, say didymium, when obtained from different sources.

We are anxiously waiting the results of this investigation, but although the paper quoted was published in July 1887, no further communication has come from these illustrious workers.

Chemists recently have stated, as proof of the existence of new elements, the fact that certain bands of absorption as seen in various fractions "follow the same variations of intensity." Before deciding the question whether didymium is a homogeneous whole, or whether an argument in favour of its heterogeneity can be based on the fact that the absorption spectra of didymium from different minerals differ *inter se*, it was necessary to ascertain if the absorption bands seen in its solutions, whatever the thickness of the layer, whether dilute or concentrated, followed the same variations, and also to ascertain the nature of these variations. To contribute to this inquiry I examined the absorption spectrum of a solution of neutral didymium nitrate containing 1 part by weight of metal in 10 of water, as seen through a series of cells from 1 mm. to 25 mm. in thickness. For this work I used a new form of binocular spectroscope, fitted with a mechanical tracing arrangement, so that each spectrum can be automatically mapped on paper strips. At the bottom, at 25 mm. thickness, all the known bands are visible, and they become fainter and die out in order, some of them remaining visible almost to the end. For instance, almost as long as the deep line in the blue part of the spectrum at $1/\lambda^2$ 507 can be distinguished, it is possible to see the group of three very narrow ones next to it. Two or three other less characteristic bands can be seen only when there is a very considerable depth of liquid; thus, the group in the red at about $1/\lambda^2$ 255 cannot be seen distinctly through less than 20 mm. of this strength of solution.

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[1] Address to the Chemical Section of the British Association, Birmingham Meeting, *Chem. News*, vol. liv. p. 123. "On the Fractionation of Yttria," *Chem. News*, vol. liv. p. 157. *Proc. Roy. Soc.*, vol. xl. (1886), p. 505.

Having ascertained in this series how the spectra varied in appearance with different thicknesses of the same solution (strength 1 of Di in 10 of water), I repeated the experiments, keeping the thickness of layer of solution constant, and diluting the standard solution of didymium so that the rays of light passed through the same quantity of metal as in the former series. The results in each case were practically identical; the differences being too slight to be detected in my apparatus. The spectrum exhibited, for instance, by 1 mm. of the standard solution of didymium is found to be identical with the spectrum shown by the same solution diluted twenty times and viewed through a 20 mm. cell.

There are at least two points in these researches that I must touch, since they illustrate the necessity of great caution in drawing conclusions from an examination of absorption spectra. Messrs. Paul Kiesewetter and Krüss (*Berichte der deutsch. chem. Gesellschaft*, vol. xxi., 2310; *Chem. News*, vol. lviii. pp. 75, 91) have recently published a paper on this subject. They have examined gadolinite, and find that some of the constituents of didymium and samarium are absent, notably the group of lines in the green to which I have already referred. In my own laboratory I have worked for the last two years almost exclusively upon the earths from gadolinite—of which I obtained a large quantity from Fahlun—and there is not the shadow of a doubt that in my gadolinite earths the lines reported absent by Kiesewetter and Krüss are present in abundance.

Some hitherto unexplained condition doubtless rendered these lines invisible to Messrs. Kiesewetter and Krüss—perhaps the presence of some other earths, or some condition of concentration or acidity. In the light of this knowledge I do not see how we can take the results of Messrs. Krüss and Nilson or my own as final.

Owing to its complicated nature, Kiesewetter and Krüss consider gadolinite an unfavourable source of didymium for these investigations, and recommend that a large quantity of earth from keilhauite should be systematically worked up, for the reason that keilhauite didymium is more simple in constitution.

THE ERBIUM GROUP.

It is known that a certain oxide, ten years ago called erbia, and regarded as belonging to a simple elementary body, has been resolved by the investigations of Delafontaine, Marignac, Soret, Nilson, Clève, Brauner, and others into at least six distinct earths—three of them, scandia, ytterbia, and terbia, giving no absorption spectra, whilst others, erbia (new), holmia, and thulia, give absorption spectra.

The first to announce that erbium was not a simple body was Delafontaine, who in 1878 (*Comptes rendus*, vol. lxxxvii. p. 556; *Chemical News*, vol. xxxviii. p. 202), published an account of philippium, a yellow oxide characterized by a strong band in the violet, λ 400 to 405, a broad black absorption band in the indigo-blue, about λ 450, two rather fine bands in the green, and one in the red.

The history of philippium is curious, and I may perhaps be allowed to give it in some detail. A year after Delafontaine's discovery, Soret (*Comptes rendus*, vol. lxxxix. p. 521; *Chemical News*, vol. xl. p. 147) published a paper in which he declared that philippia was identical with his earth X. The next month, in a note on erbia, Clève (*Comptes rendus*, vol. lxxxix. p. 708; *Chemical News*, vol. xl. p. 224) said he could not identify Soret's X with Delafontaine's philippia, as the latter was characterized by an absorption band in the blue which occupied the same place as one of the erbia bands. In February 1880 (*Comptes rendus*, vol. xc. p. 221; *Chemical News*, vol. xli. p. 72), Delafontaine returned to the subject, enumerating ten new earths in gadolinite and samarskite, viz., mosandra, philippia, ytterbia, decipia, scandia, holmia, thulia, samaria, and two others unnamed. He said that the properties of philippia were those of Soret's X and of Clève's holmia, and proposed that the name "holmia," being a duplicate name for an already known earth, should be discarded in favour of philippia. In July 1880 (*Comptes rendus*, vol. xci. p. 328; *Chemical News*, vol. xlii. p. 185), Clève repeated his former statement that philippia was not the same body as Soret's X or holmia. Delafontaine next withdrew all he had said about the absorption spectrum of philippium, and decided that it had no absorption spectrum (*Archives de Genève*, [3], 999, p. 15). Finally, Roscoe (Journ. Chem. Soc., vol. xii. p. 277), in an elaborate chemical examination of the earth-metals in samarskite, proved that philippia was a mixture of yttria and terbia. From a prolonged chemical study of these earths I have since come to a similar conclusion; but a spectroscopic examination of the earth left on igniting some specially purified crystals of "philippium formate" tested in the radiant-matter tube, has shown me that in the separation of Delafontaine's philippium the yttria undergoes a partial fractionation, and three of its components or meta-elements, $G\zeta$, $G\delta$, and $G\beta$, are present in great abundance, while others, $G\alpha$ and $G\eta$, are almost if not quite absent.

Shortly after the announcement of philippium, Soret (*Comptes rendus*, vol. lxxxvi. p. 1062) described an earth which he provisionally called X. This was soon found to be identical with an earth subsequently discovered by Clève (*Comptes rendus*, vol. lxxxix. p. 479; *Chemical News*, vol. xl. p. 125), and called by him holmia. Soret admitted the identity, and agreed to adopt Clève's name of holmia. The absorption spectrum of X consists of a very strong band in the extreme red, λ 804, two characteristic bands in the orange and green, λ 640 and 536, besides fainter lines in the more refrangible part of the spectrum.

Simultaneously with the discovery of holmia, Clève announced the existence of a second earth from erbia, which he called thulia. Its absorption spectrum consists of a very strong band in the red, λ 684, and one in the blue, λ 464·5.

In 1886 (*Comptes rendus*, cii. 1003, 1005), Lecoq de Boisbaudran showed by fractional precipitation of Soret's X, and by spectroscopic examination of the simple fractions, that this X, or holmium, consisted of at least two elements, one of which he named dysprosium, retaining the name of holmium for the residue left after deducting dysprosium. The absorption spectrum of dysprosium contains the two bands λ 753 and λ 451·5, the residual holmium having a spectrum consisting of the remaining two bands, λ 640 and 536.

PHOSPHORESCENCE SPECTRA.

I will now deal with phosphorescence spectra. Not a few chemists and physicists, conspicuous among whom is Ed. Becquerel, have carefully studied the phenomena of phosphorescence. Phosphorescence may be excited by elevation of temperature, by mechanical action, by electricity, and by exposure to the rays of the sun, and the light thus given off, for example in the case of fluor-spar, has been examined by means of the spectroscope. In my own spectroscopic research I have dealt with the phosphorescence occasioned by the impact of the molecules of radiant matter upon certain phosphorescent bodies, or what I have ventured to call molecular bombardment.

It is not necessary for me to describe the mode of procedure further than to say that the substance under examination is placed in a very high vacuum—a vacuum which varies in degree in the case of certain earths. In such a vacuum, when submitted to the action of the induction current, substances phosphoresce very differently from what they do when treated similarly at the ordinary pressure of the atmosphere. Under such circumstances the spectroscopic examination of matter affords what I have called the radiant matter test. The number of substances which are thus phosphorescent is very considerable. Glass of different kinds, according to its composition, phosphoresces with various colours. Phenakite (glucinium silicate) phosphoresces blue; spodumene (aluminium and lithium silicate) gives off a rich golden-yellow light; whilst the emerald phosphoresces crimson, and the diamond, being exceptionally sensitive and brilliant, throws off a bright greenish white light.

The ruby, one of the minerals I examined earliest in this manner, glows with a rich brilliant red tone, quite independent, as regards its depth and intensity, of the colour of the stone as seen by daylight; the pale, almost colourless specimens, and the highly-prized variety of the true "pigeon's blood," all phosphoresce with substantially the same colour.

This method of observing the constitution of the rare earths, duly aided by delicate and prolonged chemical processes, has permitted us to push our investigations further than had previously seemed practicable. It enables us to determine whether we have reached the end of our investigations—a consummation which had hitherto been vainly sought. It has enabled us to prove that yttrium, samarium, &c., are not simple, homogeneous bodies. But what of the constituents into which they have been thus resolved? Suppose we refine them down until each displays merely one spectral band—what then? Is each one of such bodies, barely differentiated from its neighbours chemically or physically, entitled to rank as an element? If so, as I pointed out in the address which I had the honour to deliver before you in March last, we shall have to deal with further perplexing questions, arising in part from the relation of such elements to the periodic system. In a discussion of the elements, not as yet published, Dr. Wundt maintains that their possible number cannot exceed seventy-nine. But I myself see no definite and sufficient reason for limitation to this number. If these bodies are not elementary, possessing as they do the properties commonly regarded as characteristic of an element, we must be prepared to show why not?

Whatever rank may ultimately be assigned to these substances, they must, for convenience sake, have names as soon as our knowledge of their properties is in a sufficiently advanced state to allow of their removal from the suspense account.

THE YTTRIUM GROUP.

Yttrium—the old yttrium—proves now to be not a simple element, but a highly complex substance. I have come to the conclusion that it may be split up certainly into five and probably into six constituents. If we take these constituents in the order of their approximate basicity—the chemical analogue of refrangibility—the lowest of these constituents gives a deep blue band, $G\alpha$; then follows a strong citron band, $G\delta$, which increases in sharpness until it may be called a line; then a red band, $G\zeta$: then a deeper red band, $G\eta$; and lastly a close pair of greenish blue lines, $G\beta$. Following these are frequently seen $G\epsilon$, $G\gamma$, and $G\theta$, the yellow, green, and red components of samarium.

A possible explanation of the existence and nature of the new bodies into which "old yttrium" has been split up, and of parallel cases which will doubtless be found on closer examination, is this. Our notions of a chemical element must be enlarged; hitherto the elemental molecule has been regarded as an aggregate of two or more atoms, and no account has been taken of the manner in which these atoms have been agglomerated. The structure of a chemical element is certainly more complicated than has hitherto been supposed. We may reasonably suspect that between the molecules we are accustomed to deal with in chemical reactions, and the conponent or ultimate atoms, there intervene sub-molecules, sub-aggregates of atoms, or meta-elements, differing from each other according to the position they occupy in the very complex structure known as "old yttrium."

The arguments in favour of the different theories are as yet not unequally balanced. But the assumption of compound molecules will perhaps account for the facts, and thus legitimate itself as a good working hypothesis, whilst it does not seem so bold an alternative as the assumption of eight or nine new elements.

I have just mentioned that the earth heretofore called yttria, and supposed to be simple, has been split up into a number of simpler bodies. Now these constituents of the old yttria are not *impurities* in yttria, any more than praseodymium and neodymium are impurities in didymium. They proceed from a real splitting up of the yttrium molecule into its components, and when this process is completed the "old yttria" has disappeared. If these newly-discovered components on further examination should be found worthy to take the rank of elements, I think, as first discoverer, I am entitled, by the custom prevailing among men of science, to name them. For the present, and until their investigation is more advanced, I designate them by provisional symbols. One of the most distinct characteristics of "old yttria" is its very definite spark spectrum. To which of its components this spark spectrum belongs I am not yet able to say. It is possible the particular component to which the spark spectrum is due yields no phosphorescent spectrum. It is also possible that the spark spectrum, like "old yttria," may prove to be compound, and then the well-known lines it contains will have to be shared between two or more of the newly-discovered bodies.

I wish emphatically to re-state that at present no single component of old yttria can lawfully lay claim to what may be called the paternal name; and it seems to me that in the present state of the question no one is entitled to call one of the new bodies "yttria," and to characterize the remainder as impurities.

INTERFERENCE OF PHOSPHORESCENCE SPECTRA.

A recent discovery of some beautiful spectra given by the rare earths when their pure oxides are highly calcined, shows the remarkable changes produced in the spectra of these earths when two or more are observed in combination. It has likewise opened to me a wide field of investigation in the nature of the elements themselves. Alumina is especially active in inducing new spectra when mixed with rare earths. I have given more than a twelvemonth to the exclusive study of alumina phosphorescence, and still the research is incomplete. But I have obtained some remarkable results. A moderate amount of fractionation has enabled me to penetrate below the surface of the red glow common to crude alumina, and to see traces of a most complicated sharp line spectrum. By pushing one particular process of fractionation to a considerable extent I have obtained evidence of a body which is the cause of some of these lines. The spectrum, described by me in 1887 (*Chem. News*, vol. lvi. pp. 62, 72), is one of great beauty. The new body is probably one of the rare elements or meta-elements closely connected with decipia, for I have reproduced the spectrum very fairly by adding decipia to alumina. Before arriving at definite conclusions much time must be devoted to the subject. Certain it is that this new earth is not yttria, erbia, samaria, didymia, lanthana, holmia, thulia, gadolinia, or ytterbia, the spectrum of each of these when mixed with alumina being very beautiful, but differing entirely from the decipia-alumina spectrum.

M. DE BOISBAUDRAN'S REVERSION SPECTRA.

Another modification of the phosphorescence process is afforded by the "reversion spectra" of M. Lecoq de Boisbaudran.

The following is the description of this process by M. Lecoq de Boisbaudran read before the Academy of Sciences on June 8, 1885:—"When the electric spectrum of a solution *with a metallic base* is produced, it is customary to make the outside platinum wire (whence the induction spark strikes) positive, the liquid consequently forming the negative pole. If the direction of the current is reversed, the metallic rays (due to the free metal or to one of its compounds) are scarcely or not at all visible; at all events, so long as the exterior platinum wire now forming the negative pole is not coated with a deposit."

M. de Boisbaudran continues:—"Having again taken up last year my researches on the rare earths belonging to the didymium and yttrium family, I had occasion to observe with many of my preparations the formation of spectrum bands, nebulous, but sometimes tolerably brilliant, having their origin in a thin layer of a beautiful green colour, which appeared at the surface of the liquid (a solution of a chloride) when it was rendered positive."

M. de Boisbaudran further adds:—"The production of my reversion spectrum appears to be analogous physically with the formation of the phosphorescence spectra obtained by Mr. Crookes at the negative pole in his high vacuum tubes containing certain compounds of yttria. The conditions of the two experiments are, however, practically speaking, very different."

By this method M. de Boisbaudran has discovered phosphorescent spectra, which he considers due to the presence of two earths, one of which, supposed to be new, he has provisionally named $Z\alpha$, and another, also thought at first to be new, and therefore called $Z\beta$, but since admitted by him to be terbia (*Comptes rendus*, vol. cviii. p. 167, January 28, 1889). In the hands of so skilful an experimentalist as my accomplished friend, this method may give trustworthy indications, but the test is really beyond the range of practical analysis, owing to the difficulty of eliciting the phenomena. Unless the strength of the spark, the concentration and acidity of the solution, and the dispersive and magnifying power of the spectroscope bear a certain proportion to each other, the observer is likely to fail in seeing a spectrum even in solutions of earths which contain considerable quantities of $Z\alpha$ and terbia.

THE PHOSPHORESCENCE OF ALUMINA.

I now wish to draw attention to some recent researches on the phosphorescence spectrum given by alumina. So far back as 1859, Becquerel examined in his phosphoroscope pure alumina carefully prepared, and described it as glowing with a splendid red colour. He rendered his specimens phosphorescent by exposure to the sun, and made no use of the induction spark. As described by Becquerel (*Annales de Chemie et de Physique*, vol. lvii., 1859, p. 50), the spectrum of the red light emitted from alumina agrees with that of the ruby when submitted to the radiant matter test. It displays one intensely red line a little below the fixed line B in the spectrum, having a wave-length of about 689·5. There is a continuous spectrum beginning at about B and a few fainter lines beyond it, but in comparison with this red line the faint ones are so dim that they may be neglected. My latest observations in the vacuum tube prove this line to be double, the distance apart of the components being about half the distance separating the D lines (Roy. Soc. Proc., vol. xlii. p. 26, December 30, 1886), their respective wave-lengths being 694·2 and 693·7 ($1/\lambda^2$ 207·5 and 207·8).

The red phosphorescence of this alumina is exceedingly characteristic. M. de Boisbaudran (*Comptes rendus*, vol. ciii. p. 1107; vol. civ. pp. 330, 478, 554, 824) contends, however, that this red phosphorescence is due, not to the alumina itself, but to an accompanying trace of chromium, 1/1100 part of chromium being sufficient to give a splendid red phosphorescence, whilst even 1 part of chromic oxide in 10,000 will produce a very distinct rose colour. In testing this view I have purified alumina most carefully, so as to secure the absence of chromium, and on examining it in the radiant-matter tube I have still obtained the characteristic phosphorescence and spectrum. I have then added to my purified alumina chromium in known varying proportions, but without finding any increase in the intensity of the phosphorescence. I fractionated my purified alumina by different methods, and found that the substance which forms the crimson line becomes concentrated towards one end of the fractionations, whilst chromium concentrates at the other end. I have suggested four possible explanations of the phenomena—

(1) The crimson line belongs to alumina, but it is liable to be masked or extinguished by some other earth, which accumulates towards one end of the fractionations.

(2) The crimson line is not due to alumina, but to the presence of an accompanying earth which accumulates towards the other end of the fractionations.

(3) The crimson line belongs to alumina, but its development requires certain precautions to be taken in the duration and intensity of the ignition, and absolute freedom from alkaline and other bodies carried down by precipitated alumina, and difficult of removal by washing.

(4) The earth alumina is a compound molecule, one only of its component sub-molecules giving the crimson one. If this hypothesis is correct, alumina must admit of being split up in a manner analogous to yttria.

CONCLUSIONS.

During the course of the investigations—whose results are briefly summarized in the foregoing pages,—I have repeatedly had recourse to the balance, to ascertain how the atomic weights of the earths under treatment were varying. An atomic weight determination is valuable in telling when a stable molecular grouping is arrived at. During a fractionation, the atomic weight of the earth slowly rises or falls until it becomes stationary, after which no further fractionation of that lot *by the same process* makes it vary. Usually a result of this kind has been relied on as proof that the elementary stage has been reached. This constancy of atomic weight, however, only proves that the original body has been split up by the fractionating process into two molecular groupings capable of resisting further decomposition by that identical process; but these groupings are not unlikely to break up when a different fractionating process is brought to bear on them, as I found in the separation of didymium and samarium when using dilute ammonia as the fractionating precipitant. In my paper on "Radiant Matter Spectroscopy" I said ("Part II., Samarium," Phil. Trans. Roy. Soc., Part 2, p. 129, June 18, 1885):—"After a time a balance seems to be established between the affinities at work, when the earth would appear in the same proportion in the precipitate and the solution. At this stage they were thrown down by ammonia, and the precipitated earths set aside to be worked up by the fusion of their anhydrous nitrates so as to alter the ratio between them, when fractionation by ammonia could be again employed."

It is obvious that when the balance of affinities here spoken of was reached, the atomic weight of the mixture under treatment would have become constant, and no further fractionation would have caused the atomic weight to alter.

Atomic weight determinations are valuable in telling when the fractionating operation in use has effected all the separation it can: at this point it becomes constant. The true inference is, not that a new earth has been obtained, but simply that the fractionating operation requires changing for another, which will cleave the group of meta-elements in a different direction.

Meantime, I have kept strictly in view the question, What is an element, and how shall it be recognized when met?

On this subject I beg to submit the following considerations, which, primarily referring to didymium, may at any moment apply to other cases:—

Neodymium and praseodymium are simply the products into which didymium is split up by one particular method of attack.

It must be remembered that a single operation, be it crystallization, precipitation, fusion, partial solution, &c., can only separate a mixture of several bodies into two parts, just as the addition of a reagent only divides a mixture into two portions, a precipitate and a solution, and these divisions will be effected on different lines according to the reagent employed. We add, *e.g.*, ammonia to a mixture, and at once get a separation into two parts. Or we add, say, oxalic acid to the same original solution, and we then split up the mixture into two other parts differently arranged.

Thus by crystallizing didymium nitrate (in Auer's way) we divide the components into two parts. By fusing didymium nitrate we divide its components in a different way; but so long as different methods of attack split up a body differently, it is evident that we have not yet got down to "bed rock."

Further, a compound molecule may easily act as an element. Take the case of didymium, which is certainly a compound, whether the products of Auer's operation be final or not. Didymium has a definite atomic weight; it has well-defined salts, and has been subjected to the closest scrutiny by some of the ablest chemists in the world. I refer particularly to Clève's classical memoir. Still the compound molecule known as didymium was too firmly held together to act otherwise than as an element, and as a seeming element it emerged from every trial. The simple operations to which it had been submitted in the preparation of its salts, and in its purification from other compound molecules, such as samarium and lanthanum, were not sufficient to split it up further. But subjected to a new method of attack it decomposes at once.

We have, in fact, a certain number of reagents, operations, processes, &c., in use. If a body resists all these, and behaves otherwise as a simple substance, we are apt to take it at its own valuation and to call it an element. But for all that it may, as we see, be compound, and as soon as a new and appropriate method of attack is devised, we find it can be split up with comparative ease. Still, we must never forget that, however complex, it can hardly be resolved into more than two parts at one operation.

From considerations above laid down I do not feel in a position to recognize neodymium and praseodymium as elements. We need some criterion for an element which shall appeal to our reason more clearly than the old untrustworthy characteristic of having not as yet been decomposed; and to this point I must beg to call the special attention of my colleagues. It may be that whatever body gives only one absorption band is an element, but we cannot conversely say that an element may be known by its giving only one absorption band, since most of our elements give no bands at all!

Until these important and difficult questions can be decided, I have preferred to open what may be figuratively called a suspense account, wherein, as I have previously suggested, we may provisionally enter all these doubtful bodies as "meta-elements."

But these meta-elements may have more than a mere provisional value. Besides compounds, we have hitherto recognized merely ultimate atoms or the aggregations of such atoms into simple molecules. But it becomes more and more probable that between the atom and the compound we have a gradation of molecules of different ranks, which, as we have seen, may pass for simple elementary bodies. It might be the easier plan, so soon as a constituent of these earths can be found to be chemically and spectroscopically distinguishable from its next of kin, to give it a name and to claim for it elemental rank; but it seems to me the duty of a man of science to treat every subject, not in the manner which may earn for him the greatest temporary κῦδος, but in that which will be of most service to science.

If the study of the rare earths leads us to clearer views on the nature of the elements, neither my colleagues nor myself will, I am sure, regret the months spend in tedious and apparently wearisome fractionations. No one can be more conscious than myself how much ground is yet uncovered, and how many radical questions have received but very inadequate answers. But we can only work on, "unresting, unhasting," trusting that in the end our work will throw some white light upon this deeply interesting department of chemical physics.

NOTES.

A MOST important and profoundly interesting letter from Mr. Stanley to the Chairman of the Emin Pasha Relief Committee has been published this week. It is dated Bungangeta Island, Ituri River, or Aruwimi River, August 28, 1888, and records the adventures of the Expedition from June 28, 1887, until the time when the letter was written. There is no more stirring tale even in the long and romantic history of African exploration. On April 29, 1888, Mr. Stanley met Emin Pasha on the shores of the Albert Nyanza Lake, and it would be impossible to over-rate the courage, energy, and resource manifested by the great traveller in grappling with the terrible difficulties which had stood in his way. Having spent some time with Emin, Mr. Stanley returned to the Aruwimi River, and reorganized what remained of Major Barttelot's force. When the letter was despatched he was on the point of starting again for the Albert Nyanza, and we may have to wait some time for further intelligence. Next week we hope to give an account of the geographical results of the Expedition, so far as they are now known.